Answering Fermi's question: Where is everybody?

Limiting our focus to our galaxy…

- [1 light year = 10 trillion km (@ 1 billion km/h)]
- Closest star is 4 l.y. away. It has a planet.
  -- If a spaceship could ever accelerate up to 1% the speed of light (10 million km/h), would still take us 400 years to get to this planet.
  -- If radio conversation: 8 year delay between responses.
- Galaxy = about 100,000 ly diameter, 200 billion stars
- [Exoplanet = extrasolar]
- Kepler space telescope has found so far:
  >1,000 exoplanets of all ages located between 10 ly to 27,000 ly
  -- 300 Earth size & in habitable zone.
  -- estimated 30,000 habitable planets within 1,000 ly.
- Recent discovery: life should easily originate on *all of them*.
- The Great Silence: 54 years of SETI has failed [*exception: Fast Radio Bursts??*]

Fermi 1950 – "where are they?"

"If they existed they would be here." → You might think there could be many advanced alien civilizations out there in space, undetectable because of the large distance. But the **time factor overcomes the distance factor…**

Universe is 13.7 billion years old; have been planetary systems in our galaxy since at least 11 billion years ago; Earth is only 4.6 billion years old.

So intelligent aliens are likely to have appeared 100s of millions of years before humans, huge amount of time to develop their civilizations.

At 1/10 the speed of light, a spacecraft can cross the galaxy in only a million years. Very doable for an alien civilization during the last billion years, expanding in steps from settlement to settlement.

More likely scenario is self-replicating robots called Von Neumann machines – the galaxy should already be flooded with these. Frank Tipler says absence *proves* we're alone, because it would take only 300 million years to saturate the galaxy, so there's been plenty of time. HOWEVER—probes might be here but *not yet detected* (*2001: A Space Odyssey*; Brin's *Existence*).

Easy to think up reason why aliens wouldn't travel, but hard to think of why they wouldn't send probes. So they should be here, ***or at least--***

Should be detectable:

Energy footprint – regardless of degree of "magic" super-technology.

One author said we are able to detect radio from a civilization at our level within 1000 ly. [NOT VERIFIED]

Type 1 alien civilization uses all energy of home planet – could perhaps be detected within 40,000 ly

Type 2 uses all energy of parent star –bright as a star, detectable in neighboring galaxy!

Type 3 uses energy of whole galaxy – really obvious.

Standard proposals for why we don't detect any of them

Most of the proposed resolutions all suffer from the consistency problem: why would all civilizations do the same thing? It only takes one exception. ***Remember*** that a galactic empire like in Star Wars is impossible because of the time lags, can't communicate.

1. transcendence – but all of them??
2. non growth, non exploring, or too much fun exploring parallel universes?—all of them?
3. They choose not to be seen, and are covering up all distant activity from view—all of them? --(*Here* one alien group could unilaterally create a fake shell of virtual reality encircling our solar system that would cover up evidence of all the others, too).
4. Self-destruct (resources need technology so can't reboot) – all of them??

More sophisticated possibilities:

Galactic Wide Web—read Davies page 118 [still: robots and footprints][*one-way*]

Oasis idea – Figure page 127. If passed by, likely millions of years ago. See a trail? Altered star spectra? A systematic depletion of comets in some star systems (fuel)?

More likely scenario: they're just not there. Why not?

(1) All went extinct

– eg due to replicating robot swarms crushing out all life (or some keeping silent). (We're next.)

Or -- from natural galaxy-wide extermination by **gamma ray bursters**. These bursts occur daily in other galaxies throughout the universe. More energy in a second than our sun in its ten billion year lifetime. IF within 1,000 ly, burst will kill all life instantly, remove the ozone layer (origin of life research shows that all alien life will have this same issue), and make planet radioactive (muons). Only microbes at bottom of ocean and inside rocks might be able to survive. Billions of years ago these happened every 3 million years in every galaxy, slowed down to every 220 million years– **SERIOUS IDEA: quote Annis paper…[phase 1 (eradication), phase 2 (setbacks), & phase 3 (transition)]**

(2) We are the only intelligent life that has ever evolved in our galaxy.

The reason is that certain evolutionary steps may be extremely unlikely during the lifetime of a planet.

The Great Filter

Cosmologist Brandon Carter & economist Robin Hanson used probability theory to show that the typical time to evolve from origin to intelligence is **longer** than the typical lifetime of a star. On Earth we used up about 4 billion years of our allotted 5 billion (when we get fried by the sun; we have 800 million years left before doomsday). They predict that about 6 improbable steps are needed, and that these would be evenly distributed in time (800 m.y. intervals). This might match the fossil record: origin, photosynthesis*, eukaryote cells*, sexual reproduction, animals, brainy hominids. We may have been faster than the majority of stars and got through the Great Filter. (E.g. Gribbon 2011 – periodic interglacials selected for fast evolution of intelligence here).

*NICK LANE: reversal of what we used to expect:

(1) Origin is inevitable and early [quick summary*—flash vent photo & illustration], vents on all Earthlike planets, even moons like Europa (__). Makes "weird life" improbable. **But…**

(2) The next two steps are extremely improbable, lucky accident [quick summary*]
Result: 30,000 worlds with nothing but pond scum. No animals outside Earth.

- REBUTTAL by de Duve 2005 – because endosymbiosis happened a second time with chloroplasts, he suggests a range of such events happened during a "selective bottleneck" optimized by natural selection –thus not a lucky accident, therefore animal aliens much more probable.
- REBUTTAL #2 THIS YEAR: BLEBS (archaea do this, show cell wall molecules in nucleus/ER). →[still leaves photosynthesis as weak link]

Intelligence is not inevitable.

Smartest dinosaurs with hands had 12 million years. Marsupials independently in Australia had 50 million years [second test, parallel world, got nothing]. The primates in the Americas had 170 million years [third test, nothing]. So even on Earth it could easily have not ever happened.

My concluding calculation (c.f. Drake equation p 77):

Earthlike planets in habitable zone: 30% of stars **x** ½ galactic habitable zone **x** 0.2% moons* = 0.04% [*Gribbon 2011 – need large moon to stabilize the tilt and generate plate tectonics]. So 200 billion stars **x** 0.04% earthlike **x** 100% life emerges = 80 million planets with life… BUT →animal life→technological intelligence (1/million)(1/100)=1/100million = 1 (us).

====================APPENDIX=================================

For Discussion time: SETI

So far SETI Institute has checked a few thousand stars within 100 ly. – large frequency range radio, optical laser.

Remember, they don't know we're here. A civilization 1,000 ly away looking at us will see us in AD 1014. All stars within 50 ly have been searched. Also, alien domestic transmissions are too weak to detect (and a short-lived phase); it has to be a deliberate, high energy signal.

Three reasons the SETI Institute may be looking in the wrong place:

1. Radio broadcast phase of a civilization is too short. Synchronization issue – ***neighborhood lights*** analogy. How long do they last?

2. Assuming a continuous high energy (high cost) beacon broadcasting in all directions for hundreds of millions of years. Benford – better strategy is narrow beam of wide bandwidth in cyclic sequence of pings to prospects (like one second every year) = 1 millionth energy. C.f. SETI is narrowly receiving, assuming a narrow band continuous broadcast. Broad receiving can easily be done with a global amateur network. Pings like this have been detected but not followed up on, e.g. the famous "Wow!" signal in 1977. **Recent: Fast Radio Bursts** (see journal)**.**

3. Sending a physical information artifact – one way communication, makes more sense because of the long time issue; it could orbit for a hundred million years waiting to be found. Two way communication is impossibly slow. Nanotech takes little energy, replicate along the way, and grow large when it got here. There's no such thing in low orbit, but SETI scientists are searching the Lagrange points.

Reiterate: lack of contact tells nothing about existence; more important to look for large scale effects.